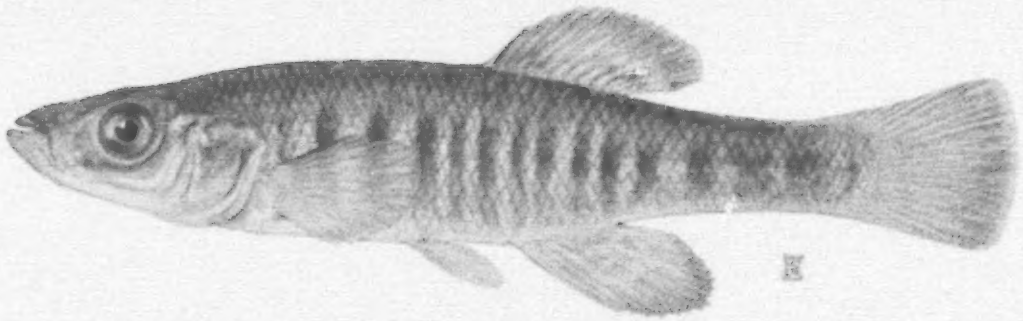
COSEWIC
Assessment and Status Report

on the

Banded Killifish
Fundulus diaphanus

Newfoundland populations

in Canada



SPECIAL CONCERN
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Previous report(s):

COSEWIC. 2003. COSEWIC assessment and update status report on the banded killifish *Fundulus diaphanus*,Newfoundland population in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 21 pp.

Chippett, Jamie D. 2003. Update COSEWIC status report on the banded killifish *Fundulus diaphanus*,Newfoundland population in Canada, *in* COSEWIC assessment and update status report on the banded killifish *Fundulus diaphanous* in Canada. Committee on the Status of Endangered Wildlife in Canada). Ottawa. 1-21 pp.

Houston, J.J.P. 1989. COSEWIC status report on the banded killifish *Fundulus diaphanus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 22 pp.

Production note:
COSEWIC would like to acknowledge Dr. Tim Birt for writing the status report on the Banded Killifish, *Fundulus diaphanus*, Newfoundland populations, in Canada, prepared under contract with Environment Canada. This report was overseen and edited by Dr. John Post, Co-chair of the COSEWIC Freshwater Fishes Specialist Subcommittee.

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Banded Killifish — Provided by author.

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COSEWIC
Assessment Summary

Assessment Summary – May 2014

Common name
Banded Killifish - Newfoundland populations

Scientific name
Fundulus diaphanus

Status
Special Concern

Reason for designation
This species has a scattered distribution in insular Newfoundland and occupies a small area of occupancy. The species can be impacted negatively by turbidity and hydrological alterations that result from road, forestry, cottage, and hydrological development. It could become Threatened if these impacts are not managed or reversed with demonstrable effectiveness.

Occurrence
Newfoundland and Labrador

Status history
Designated Special Concern in April 1989. Status re-examined and confirmed in May 2003 and May 2014.

COSEWIC
Executive Summary

Banded Killifish
Fundulus diaphanus

Newfoundland populations

Wildlife Species Description and Significance

The Banded Killifish is a small fish (family Fundulidae) that reaches a maximum size of approximately 120 –130 mm in length. It has a flat head and an upward-pointing mouth. The dorsal surface is brown to olive-coloured that fades to silver or cream colour below. The species has vertical bands over most of the body that are more closely spaced in males than females. Another sexually dimorphic feature is observed during the spawning period when males develop a bluish hue of varying intensity around the anal fin. The Banded Killifish is one of two cyprinodonts in insular Newfoundland. Where present, it is a significant member of Newfoundland's freshwater fish communities, which are characterized by low species diversity. The Newfoundland populations of Banded Killifish are situated on the eastern periphery of the species' range and may harbour unique adaptive genetic variation (e.g. spawning occurs during summer months while mainland populations are spring spawners).

Distribution

The Banded Killifish is distributed throughout much of eastern North America including the Atlantic provinces and most of the Great Lakes-St. Lawrence basin. In Newfoundland, the species has a scattered distribution but is concentrated along the southwest coast (Grand Bay West, Loch Leven, St. George's Bay, Bay of Islands, and Cow Head). Other apparently disconnected populations in Newfoundland are present on Ramea Island, the northeast coast (Indian Bay Watershed), the Burin Peninsula (Freshwater Pond, Winterland, and Garnish Pond) and in the headwaters of the Exploits River (Star Pond). An introduced population is present in Burton's Pond, St. John's. Ten locations are known, although recent survey work suggests the possibility of additional unknown locations.

Habitat

This species is most often found in fresh water although sometimes it occupies estuaries. It requires shallow water, slow currents, soft substrates, and abundant aquatic vegetation.

Biology

Mainland populations of Banded Killifish reproduce during the spring. Spawning has been reported in Newfoundland's Indian Bay watershed from late June through August. The species does not appear to become active in Newfoundland until water temperature reaches 12°C. Adhesive eggs are attached to aquatic plants; there is no parental care provided to young. Young-of-the-year attain a size of approximately 40-50 mm by October of the first year. The species is a feeding generalist, consuming a variety of invertebrate prey items captured throughout the water column in the shallow littoral zone. Maturity is achieved at 1 year of age. Although usually found in freshwater habitats, the Banded Killifish is euryhaline, i.e. it is also capable of living in habitats with elevated salinities.

Population Sizes and Trends

No data are available with regard to population trends. A single population estimate for the Indian Bay watershed site of 12,529 - 40,201 individuals is the only abundance data available. Populations at Loch Leven and Freshwater Pond have been described as abundant. Although data are limited, there is no indication of decline in either the number of populations or abundance within populations.

Threats and Limiting Factors

The most significant threat appears to be sedimentation resulting from forest harvesting activity and road construction/maintenance. Altered water flow regimes and obstruction of fish passage caused by road development/maintenance and other development also threaten the species in Newfoundland. Other potential (but not imminent) threats include pollution caused by road construction, mining activity and cabin development, the bait fishery, and predation by invasive non-native salmonid fishes. The low occupancy of apparently abundant suitable habitat is thought to reflect the low capacity for inland dispersal from coastal areas due to an inability to negotiate rapids and waterfalls.

Protection, Status, and Ranks

Banded Killifish (Newfoundland populations) is listed as Special Concern under Canada's *Species at Risk Act* and as Vulnerable under Newfoundland and Labrador's *Endangered Species Act*. The species is ranked as secure globally (G5) and nationally (N5 in Canada and the United States). State and provincial ranks are variable, ranging from S5 through S1 (NatureServe 2013). Lower risk rankings apply in most states and provinces.

TECHNICAL SUMMARY

Fundulus diaphanus
Banded Killifish
Newfoundland Populations

Fondule barré
Populations de Terre-Neuve

Demographic Information

Generation time Mature at 1 year. Maximum age is 4 years in Newfoundland; 3 years in Minnesota. Few individuals attain these ages.	1- 2 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	NA
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	NA
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence Minimum convex polygon method	73,639 km²
Index of area of occupancy (IAO) Estimated assuming one 2x2 grid per location.	48 km²
Is the population severely fragmented?	No
Number of locations Indian Bay watershed Freshwater Pond/Winterland (Burin Peninsula) Garnish Pond (Burin Peninsula) Ramea Island Star Lake* Loch Leven St. George's Bay (several sites including Pinchgut Pond*) Grand Bay West* (First Pond) Bay of Islands* (York Harbour) Cow Head* *Populations discovered since 2003 Update Status Report	≥10
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No

Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	No
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Total	Unknown
Indian Bay watershed	20,569 (12,529-40,201)
Freshwater Pond (Burin Peninsula)	Unknown
Winterland (Burin Peninsula)	Unknown
Garnish Pond	Unknown
Ramea Island	Unknown
Star Lake	Unknown
Loch Leven	Unknown
St. George's Bay	Unknown
Grand Bay West (First Pond)	Unknown
Bay of Islands (York Harbour)	Unknown
Cow Head	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not done

Threats (actual or imminent, to populations or habitats)

Increased sediment loads resulting from forest harvesting and alteration in land use (e.g. road development and maintenance). Additional potential threats (i.e. not identified as actual or imminent at present) include invasive non-native salmonid species, bait harvesting, and pollution (due to mining, urban development and cottage development).

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Secure in the three Maritime provinces	S5 rankings
Is immigration known or possible?	Unknown
Would immigrants be adapted to survive in Newfoundland?	Probably
Is there sufficient habitat for immigrants in Newfoundland?	Yes

*See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Is rescue from outside populations likely?	Unlikely

Data-Sensitive Species

Is this a data-sensitive species?	No

Status History

COSEWIC: Designated Special Concern in April 1989. Status re-examined and confirmed in May 2003 and May 2014.

Status and Reasons for Designation:

Status:	**Alpha-numeric code:**
Special Concern	Not applicable
Reasons for designation: This species has a scattered distribution in insular Newfoundland and occupies a small area of occupancy. The species can be impacted negatively by turbidity and hydrological alterations that result from road, forestry, cottage and hydrological development. It could become Threatened if these impacts are not managed or reversed with demonstrable effectiveness.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Insufficient information available on the abundance of mature individuals.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Area of occupancy is small, with possibly more than 10 locations, but no evidence of continuing declines in distribution, number of locations or the number of mature individuals. Quality of habitat is projected to decline due to ongoing development.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Insufficient information available on the abundance of mature individuals.
Criterion D (Very Small or Restricted Population): Not applicable. Insufficient information available on the abundance of mature individuals.
Criterion E (Quantitative Analysis): Not applicable. A quantitative analysis has not been done.

PREFACE

The Banded Killifish has a scattered distribution in insular Newfoundland, although populations along the southwest coast are more concentrated. Recent survey work has revealed previously unknown populations, particularly in the St. George's Bay area and suggests the species has a wider distribution than that reported in the last Update Status Report (Chippett 2003). Unconfirmed reports exist of populations in the Main Brook area on the Great Northern Peninsula and Western Brook in Gros Morne National Park. In general, information relating to abundance within populations is lacking although local knowledge indicates the species is abundant at three sites (Indian Bay watershed, Freshwater Pond, and Loch Leven). Since the last COSEWIC Update Status Report, estimates of extent of occurrence and area of occupancy have increased slightly.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2014)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

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Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Banded Killifish

Fundulus diaphanus

Newfoundland populations

in Canada

2014

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Actinopterygia

Order: Cyprinodontiformes

Family: Fundulidae

Scientific Name: *Fundulus diaphanus* (Lesueur 1817)

English Common Name: Banded Killifish

French Common Name: Fondule barré

Two subspecies of Banded Killifish are recognized (Hubbs and Lagler 1964; Slastenenko 1958). The eastern subspecies *Fundulus diaphanus diaphanus* differs from the western subspecies, *F. d. menona*, in several respects; the former is larger, has more highly pigmented vertical bars in the anterior part of the body, has more scale rows, and has more dorsal and anal fin rays than the latter subspecies.

Morphological Description

Like other members of its genus, the Banded Killifish is a small fish with a flattened head and an upward-directed mouth. These features allow the fish to rest and feed at the surface, hence one of the common names, topminnow. It is a soft-rayed fish with a rounded caudal fin and cycloid scales. The typical total length for the eastern *F. d. diaphanus* is approximately 110 mm while the western *F. d.* menona reaches a maximum length of 74 mm (Hubbs and Lagler 1964). The largest individual sampled in Newfoundland was from the Indian Bay watershed and measured 128 mm (Chippett 2003). The dorsal surface of the Banded Killifish is olive-green to dark brown while the sides and ventral surface are white or yellowish white. The sides and back are decorated with a variable number (usually 12 – 20) of dark vertical bars. The species is sexually dimorphic. Females have fewer and more widely spaced vertical bars (Holm *et al.* 2009), and during the breeding season males develop a bluish hue around the anal fin (Scott and Crossman 1973).

Population Spatial Structure and Variability

The eastern subspecies, *Fundulus diaphanus diaphanus*, is present in the Atlantic drainage and Great Lakes-St. Lawrence drainage as far west as eastern Lake Ontario where it intergrades with the western subspecies, *F. d. menona*. Fish of the eastern subspecies, including Newfoundland populations, are larger than fish from the western subspecies (maximum 110 mm versus 74 mm) and differ in several morphological and meristic characters. The dorsal fin is situated more anteriorly in *F. d. diaphanus* and this subspecies has more vertical bars along the flanks than *F. d. menona*. Furthermore, *F. d. diaphanus* has more lateral line scales (45-49 v.s. 40-44) and higher ray counts in the

dorsal and anal fins (24-26 v.s. 23-34, combined counts) (Trautman 1957; Hubbs and Lagler 1964). Genetic differentiation of the subspecies is evident in the mitochondrial genome (April and Turgeon 2006) and at microsatellite loci in the nuclear genome (Rey and Turgeon 2007). It is unclear if the Newfoundland populations are differentiated from mainland populations. Chippett (2004) found very low levels of allozyme variation and no apparent differentiation in Banded Killifish from Indian Bay watershed, Freshwater Pond, Loch Leven, and one mainland population. Analysis of more rapidly evolving markers will be required to determine if the Newfoundland populations are genetically distinct from mainland populations (and from each other). Chippett (2004) also found no consistent differentiation in morphometric and meristic characters among these populations that would suggest genetic differentiation.!

Designatable Units

To be eligible for COSEWIC status assessment, biological units below the species level must be considered discrete and evolutionarily significant (i.e. they must represent distinct designatable units (DUs)). The Newfoundland DU is discrete for two reasons: 1) it occupies a separate National Freshwater Biogeographic Zone (the Atlantic Islands Zone) than mainland DUs, and 2) there is a natural range disjunction that imposes a strong barrier to dispersal between Newfoundland and mainland DUs. Although Banded Killifish has high salinity tolerance, movement across the Gulf of St. Lawrence is probably very infrequent. The species is not present along the mainland side of the Strait of Belle Isle, so dispersal across this barrier is also improbable.

The Newfoundland DU is probably also evolutionarily significant. Insular Newfoundland is a large landmass that represents a considerable fraction of the range of Banded Killifish. Loss of these populations would create a sizeable gap in the Canadian range of the species. Newfoundland also constitutes the northern and eastern extreme of the species' global range and populations there are considered to be peripheral. Peripheral populations have been suggested to have special evolutionary significance because, in many cases, they are subjected to different selective pressures relative to those in the core range (Eckert *et al.* 2008). Such novel selective pressures can, over time, result in retention of new adaptive genetic variation. Some evidence suggests local adaptation in the Newfoundland DU. Fecundity and egg size of Banded Killifish in the Indian Bay watershed appear to be greater than in fish from mainland populations (Cooper 1936; Carlander 1969; Chippett 2004), although these differences could also be explained by the slightly larger mean size of fish from Newfoundland (Chippett 2004). Larger body size could also reflect genetic differentiation from mainland populations. Additional evidence for local adaptation in the Newfoundland DU includes different spawning time. Banded Killifish in the Indian Bay watershed spawn during the summer months (Chippett 2004) while mainland populations spawn considerably earlier during the spring months (Carlander 1969; McAllister and Coad 1974). Habitat variables that could potentially drive local adaptation in Newfoundland populations include water chemistry parameters and seasonal light/temperature profiles that differ from those encountered in mainland populations.

Although Chippett (2004) did not observe differentiation of Newfoundland and Mainland DUs at 11 allozyme loci, this should not be interpreted as strong evidence for genetic homogeneity among DUs. Allozymes are very conservative molecular markers and an analysis using more sensitive markers would be much more likely to detect differences. The evidence for evolutionary significance of the Newfoundland DU is not conclusive but, in light of the information suggesting local adaptation, and until more informative genetic data are available, populations of Banded Killifish in Newfoundland are best considered to be a separate DU from mainland populations.

Special Significance

All of the freshwater fishes native to Newfoundland, including the Banded Killifish, are secondary freshwater species (Underhill 1986). The biodiversity of the Newfoundland freshwater fish fauna is low, so the Banded Killifish contributes significantly to the overall biodiversity of the communities in which it occurs. The species is considered to be a forage fish for Brook Trout (*Salvelinus fontinalis*) and Atlantic Salmon (*Salmo salar*), two important native sport fishes.

DISTRIBUTION

Global Range

Banded Killifish has a large distribution across eastern North America. The range extends from insular Newfoundland and the Gaspé Peninsula, through the Maritime Provinces and eastern seaboard as far south as South Carolina. The species is present throughout most of the St. Lawrence-Great Lakes drainage (although absent from most of Lake Superior). There is one record from the Red River in Manitoba (Stewart-Hay 1954). In the U.S. the species occurs throughout the Great Lakes drainage states and in a few Mississippi drainage states including New York, Pennsylvania, Michigan, Wisconsin, Illinois, and Nebraska (Scott and Crossman 1973; Froese and Pauly 2013).

Newfoundland Range

Populations of Banded Killifish in insular Newfoundland appear to be scattered in coastal freshwater and brackish habitats. Figure 1 shows sites where the species has been confirmed. The first record was by Templeman (1951), who observed fish in brackish water near the head of St. George's Bay. Subsequently, the species was reported from nearby Loch Leven and from Freshwater Pond on the Burin Peninsula (Gibson *et al.* 1984). In 1993, a single specimen was collected in Second Pond in the Indian Bay watershed. Seven additional specimens were collected in different lakes in the same watershed (Backup Pond and Third Pond) in 1997. A substantial population is now known to exist in the Indian Bay watershed (Chippett 2004). Four specimens were collected on Ramea Islands off the south coast of Newfoundland (Day 1993). In 1999 a single specimen was angled from a pond in Winterland (Burin Peninsula) near Freshwater Pond (Chippett 2004). A population of Banded Killifish was discovered in

2002 in the Grand Bay West area (First Pond) in western Newfoundland near Port aux Basques (Mann and Nambudiri 2005) and populations have also been reported in the Exploits watershed (Star Lake) and in a lagoon near York Harbour in the Bay of Islands (Chippett 2004). A population is also present in Burton's Pond on the St. John's campus of Memorial University of Newfoundland (Griffiths, pers. comm.). This is thought to be an introduced population that is successfully reproducing (Purchase, pers. comm.). Several additional sites near St. George's Bay have recently been found to support Banded Killifish (Gallant, pers. comm.) and unconfirmed reports have been made on the Great Northern Peninsula near Main Brook (Chippett 2004) and in Western Brook in Gros Morne National Park (Whitaker, pers. comm.). Finally, two populations were discovered in 2013, one in a lake (Pinchgut Pond) on Harry's Brook and a second in the Cow Head water supply near Gros Morne National Park (Whitaker, pers. comm.).

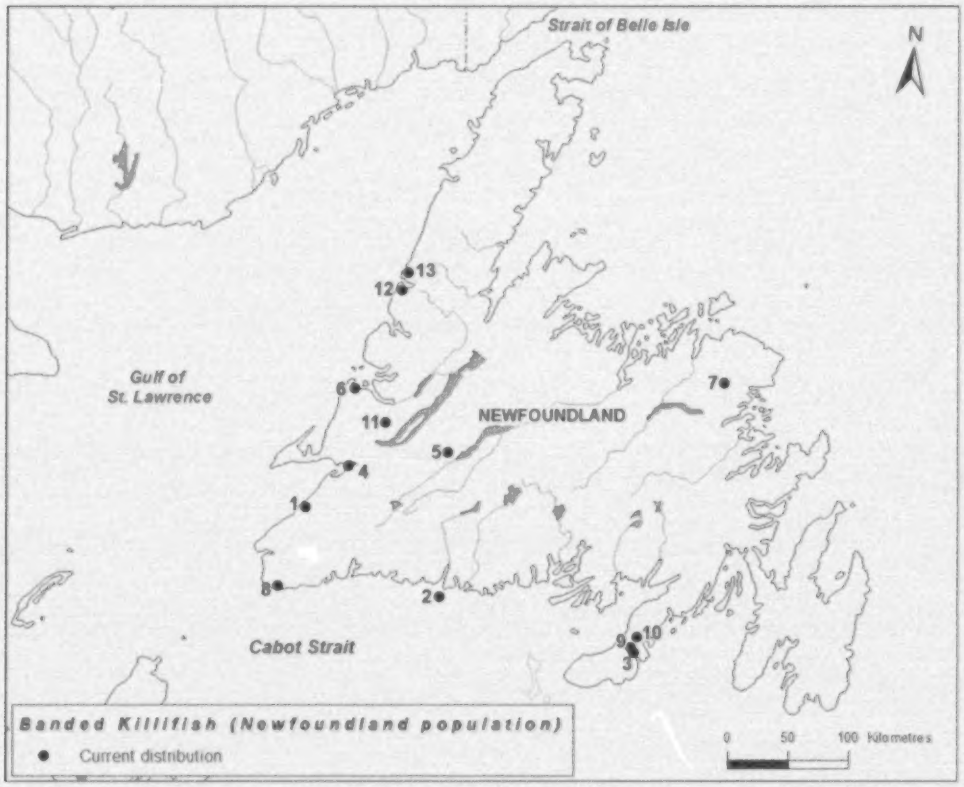

Figure 1. Distribution of Banded Killifish in insular Newfoundland. Dots represent sites where the species has been observed: 1 Loch Leven, 2 Ramea Island, 3 Freshwater Pond, 4 St. George's Bay, 5 Star Lake, 6 Bay Of Islands (York Harbour), 7 Indian Bay watershed, 8 Grand Bay West (First Pond), 9 Winterland, 10 Garnish Pond, 11 Pinchgut Pond, 12 Western Brook (unconfirmed), and 13 Cow Head. Additional sites have been identified in St. George's Bay and a report in the Main Brook area of the Great Northern Peninsula has not been confirmed.

The Banded Killifish in the Indian Bay watershed appears to be limited to a relatively small area including the southern end of Backup Pond and the eastern end of Third Pond. Fyke net surveys were conducted each summer during 1993 – 2000, and almost all fish were captured in this small area despite the widespread occurrence of apparently suitable habitat throughout the system (Chippett 2004).

Extent of Occurrence and Area of Occupancy

Extent of occurrence was estimated to be 73,639 km^2 using the minimum convex polygon method. IAO was estimated to be 48 km^2 by applying one 2x2 km to each of twelve sites where presence is confirmed (the Burton's Pond site was not included because it is probably an introduced population). This is justified because several of the water bodies containing Banded Killifish in Newfoundland are small (e.g. Loch Leven, Ramea Island) and the distribution of the species within the various occupied water bodies is sometimes quite limited (see below).

Search Effort

Search effort prior to the last COSEWIC Status Update (Chippett 2003) included fyke net and/or electrofishing surveys at a number of sites in central Newfoundland including Notre Dame and Beothuk Provincial Parks and the Millertown area. Searches were also done in collaboration with Parks Canada, DFO, and Memorial University personnel in Gros Morne and Terra Nova National Parks. Searches in Gros Morne National Park included 20 sites (14 watersheds) in coastal areas with unobstructed access to the marine environment (Knight 2002). Surveys in eastern Newfoundland were conducted at sites on the Avalon Peninsula, Mint Brook (Gambo River drainage), Winterton area, and Hants Harbour. Additional survey work on the Great Northern Peninsula near Main Brook was also done. No Banded Killifish were collected in any of these attempts.

Since the last COSEWIC Status Update (Chippett 2003), surveys have been conducted in 2006 at a number of sites in the St. George's Bay area by personnel of the Mi'kmaq Alsumk Mowimsikik Koqoey Association. These surveys located several additional populations of Banded Killifish (MAKMA 2006; Roger Gallant, pers. comm.). Survey work in 2013 in the Gros Morne area revealed Banded Killifish in the water supply pond at Cow Head and in Pinchgut Pond (Harry's Brook). A credible but unconfirmed report of the species in Western Brook was also made (Whitaker, pers. comm.).

HABITAT

Habitat Requirements

Banded Killifish has been described as a habitat generalist (Brind'Amor *et al.* 2005). It is usually found in shallow areas characterized by clear water, low current, sandy or muddy substrate, and aquatic vegetation (Scott and Crossman 1964, 1973; Houston 1990; Chippett 2004; Valley *et al.* 2010). The species is usually found in fresh water despite having high salinity tolerance like the closely related Mummichog, *Fundulus heteroclitus* (Fritz and Garside 1974a). In Newfoundland, Chippett (2004) reported that areas in lakes where Banded Killifish were observed had variable substrates including fine mud, sand, gravel or cobble. In the Indian Bay watershed, the most common aquatic plants in areas containing the species, as determined by quadrat sampling, are Water Lobelia (*Lobelia dortmana*), Quillwort (*Isoetes* sp.) and Pipewort (*Eriocaulon* sp.). Other common aquatic macrophytes include Eastern Purple Bladderwort (*Utricularia purpurea*), Pondweed (*Potamogeton epihydrus*), and Water Milfoil (*Myriophyllum tenellum*). Banded Killifish has a broad thermal tolerance (see below), although in Newfoundland, it is most active during the warmest part of the summer.

Habitat Trends

Apparently suitable habitat is common and widespread in Newfoundland, yet mostly unoccupied by Banded Killifish. While widespread deterioration in habitat quality in the lakes harbouring the species has not been documented, there has been some activity in the watersheds that may affect habitat quality. In particular, forest harvesting activities, especially road construction, have the potential to degrade habitat through elevation of sediment loads. At present, little forest harvesting is occurring in the area where most Banded Killifish populations are situated, i.e. the south and southwest coasts (Fisheries and Oceans Canada 2011). In contrast, clear cutting has been scheduled for part of the Indian Bay watershed. Specifically, an area along the south shore of Indian Bay Big Pond is included in the commercial harvest plan for 2014. The plan includes extending a winter class road into the area from the west while maintaining a 200 m no-cutting buffer along the lake shore (Newfoundland and Labrador Department of Natural Resources 2014 Commercial Harvest Plan Map; Parkes, pers. comm.). In general, the quality of Banded Killifish habitat in Newfoundland remains high.

BIOLOGY

Life Cycle and Reproduction

Banded Killifish mature at one year of age. Mature males develop more intense pigmentation during the spawning season, in particular the body around the anal fin becomes bright blue (Scott and Crossman 1973; Chippett 2004). Males become territorial and aggressively exclude rivals while courting females. Externally fertilized eggs are bound to aquatic plants by an adhesive thread (Richardson 1939). Spawning has been reported in mainland populations in April and May when water temperatures reach approximately 21 °C or higher (Carlander 1969; McAllister and Coad 1974). In Newfoundland (Indian Bay watershed) spawning occurs in late June through August at temperatures of 19-23 °C; *Potamogeton* is the plant most often used as spawning substrate (Chippett 2004). Banded Killifish in the Indian Bay system appear to have higher fecundity and larger eggs than fish in some mainland populations. Chippett (2004) reported mean egg diameter for Indian Bay watershed Banded Killifish to be 2.2 mm and maximum fecundity of 450 eggs. Cooper (1936) found mean egg diameter for mainland killifish to be 2.0 mm and Carlander (1969) reported maximum fecundity of 250 eggs for mainland killifish.

Young of the year undergo approximately linear growth during their first summer in Lake Opinicon, Ontario. They reach a mean length of 49.5 mm by the middle of October, by which time growth essentially ceases until water temperatures increase the following spring (Keast and Eadie 1984). Information on growth patterns in populations in Newfoundland is not available. Similarly, information on lifespan is limited. The maximum age for Banded Killifish in Newfoundland is 4 years (Fisheries and Oceans Canada 2011), although most probably die earlier. In Minnesota, few live as long as 3 years (Paulson and Hatch 2002). Generation time is estimated as 1-2 years.

Physiology and Adaptability

Banded Killifish is versatile physiologically, having broad tolerance for variation in temperature, salinity, and dissolved oxygen. Populations from different regions appear to vary in temperature preference. Melinsky *et al.* (1980) reported that fish from Pennsylvania have higher preferred temperature than fish from Nova Scotia (28.6 °C versus 21.0 °C). Similarly, while Rombough and Garside (1977) reported an upper incipient temperature limit of 34.5 °C, Carlander (1969) observed fish at a temperature of 38.3°C. The Banded Killifish is not generally active at low temperature. Chippett (2004) observed that the species is catchable with fyke nets in the Indian Bay watershed in eastern Newfoundland only when water temperature reached 12°C.

Like its frequently sympatric congener, the Mummichog, the Banded Killifish is euryhaline. Both species are capable of acclimation to full-strength sea water, although the two species differ in salinity preference. Banded Killifish prefers fresh water while the Mummichog selects intermediate salinities when exposed to a salinity gradient (Fritz and Garside 1974a).

The Banded Killifish feeds on many prey items including benthos and flying insects (Keast and Webb 1966; Scott and Crossman 1973). Specific items identified in gut content analyses of fish from Lake Opinicon, Ontario, include chironomid larvae, cladocerans, copepods, ostracods, and amphipods (Keast and Webb 1966; Keast 1980).

Dispersal and Migration

In general, the Banded Killifish is not considered to be migratory and seasonal movement has not been documented. The species likely departs the shallow littoral zone for deeper water in the autumn, as has been observed in the closely related Blackstripe Topminnow (*Fundulus notatus*, Carranza and Winn 1954). The Banded Killifish is not a strong swimmer and movement within watersheds is limited by high water velocity (Fisheries and Oceans Canada 2011). The extent of movement within watersheds in which steep gradients are not present appears to vary by location. Banded Killifish in the Indian Bay watershed are apparently restricted to parts of Backup Pond and Third Pond despite the absence of physical barriers beyond these areas. The occupied areas are typically shallow and have extensive vegetation. However, fyke net catch data suggest that some nocturnal movement out of these areas into deeper rocky habitats may occur in these lakes (Chippett 2004). In contrast, movement in a glacial lake in Minnesota may be more extensive. Valley *et al.* (2010) found that the mean displacement distances of marked and recaptured individuals were 228 m and 355 m between the months of May and August in two separate years. They also reported that some individuals were observed to travel the length of the lake within sampling seasons, sometimes over brief time intervals. Variation in displacement distances in different lakes is consistent with the finding of Woolnough *et al.* (2009) that lake size and shape strongly influence this behaviour in freshwater fishes.

Although Banded Killifish is usually found in fresh water, a high level of salinity tolerance allows the species to enter estuaries and even full-strength sea water. In Newfoundland, estuary use is suspected to be more extensive than previously thought (Fisheries and Oceans Canada 2011). The route(s) taken by Banded Killifish to colonize insular Newfoundland is not certain, but presumably involved crossing an expanse of deep, highly saline water (Underhill 1986). While such dispersal would be difficult and presumably very rare, the concentration of populations in southwest portion of the island is consistent with this notion. Estimating the timing of the initial colonization of Newfoundland will require additional population genetic data.

Interspecific Interactions

Sympatry of Banded Killifish and Mummichog in many areas along the Atlantic coast of North America enables various interspecific interactions to occur. In several localities, usually in brackish habitats, the two species form mixed shoals (Blakeslee *et al.* 2009). In Newfoundland, this behaviour is restricted to populations along the southwest coast (Fisheries and Oceans Canada 2011). Heterospecific (and conspecific) shoals are size-selected, i.e. individual fish prefer to associate with other individuals of similar size (Blakeslee *et al.* 2009).

Banded Killifish and Mummichog also hybridize. Hybrids have been described by Hubbs *et al.* (1943) from Prince Edward Island, Griffith (1968) from Mill River in Connecticut, and Fritz and Garside (1974b) from Porter's Lake, Nova Scotia but not from Newfoundland. Fritz and Garside (1974b) noted that all hybrids sampled from Porter Lake were female F_1 individuals, i.e. there was no evidence of back crossing. Additional study of this population and others in the Maritime provinces indicated the presence of both sexual and clonal hybrid populations (Dawley *et al.* 1999; Hernández Chávez and Turgeon 2007).

A number of species are known to prey on Banded Killifish and, where the latter is abundant, it can be important forage fish. Atlantic Salmon, Brook Trout, American Eel (*Anguilla rostrata*), Brown Trout (*Salmo trutta*), and Rainbow Trout (*Oncorhynchus mykiss*) are known to consume Banded Killifish. Birds, including Belted Kingfisher (*Megaceryle alcyon*) and Common Merganser (*Mergus merganser*), also prey on Banded Killifish (Chippett 2003; Fisheries and Oceans Canada 2011).

POPULATION SIZES AND TRENDS

Sampling Effort, Methods, and Abundance

The only quantitative estimate of population size in Newfoundland was done in 1999 for the population in the Indian Bay watershed (Chippett 2004). Snorkelling and/or fyke net sampling were performed at 22 sites in the watershed. Banded Killifish were observed in three lakes (four sites), including Third Pond, Backup Pond, and Indian Bay Big Pond. Only a single specimen was observed in Indian Bay Big Pond. Using the Schnabel mark-recapture method, a population size estimate of 20,569 individuals (95 % CI 12,529 – 40,201) was obtained during August when water temperature was at the seasonal maximum. An earlier estimate at the same sites, made in July when water temperature was lower, was 1209 individuals (95% CI 619 – 3,423). Chippett (2004) also provides catch per unit effort information for the populations in Indian Bay watershed, Freshwater Pond, and Loch Leven (Table 1). Although the catch per unit effort is highest in the Indian Bay watershed, the relative sizes of the populations are not known because the sizes of the occupied areas in Freshwater Pond and Loch Leven are not known.

Table 1. Catch per unit effort of Banded Killifish in three sites in Newfoundland in 1999. Fyke net design is described in Chippett (2004). Nets were fished for approximately 24 hours per set.

Population	Net Sets	Fish Caught Per Net Set
Indian Bay	24	42
Loch Leven	10	29
Freshwater Pond	10	23

Fluctuations and Trends

There is no time series of population estimates for Banded Killifish in Newfoundland. Houston (1990) reported the species to be common in Loch Leven and Freshwater Pond. Chippett (2004) noted that schools of approximately 25 – 40 fish could easily be observed in Loch Leven. Catch per unit effort estimates in three lakes (Table 1) suggest that the species is abundant, and cabin owners near Freshwater Pond also described Banded Killifish as abundant at that site (Chippett 2004).

Rescue Effect

The closest populations of Banded Killifish to insular Newfoundland are in the Maritime provinces. Even though the species is euryhaline and is known to sometimes occupy estuarine habitat, it is predominantly a freshwater fish. Rescue from mainland populations would entail crossing the Cabot Strait, a distance of more than 100 km, through the marine environment. While not impossible, such dispersal events for a small, relatively weak-swimming fish would be expected to be very rare. As indicated above, the concentration of populations in southwest Newfoundland is consistent with some (probably low) level of dispersal from the mainland. Furthermore, the coastal distribution of the species in Newfoundland suggests that colonization of new freshwater areas has occurred via the marine route. On the other hand, the scattered distribution of the species in Newfoundland and its absence from many presumably suitable and accessible watersheds along the west coast, suggests that dispersal through the marine environment is rare. Otherwise, the species would be expected to have colonized unoccupied watersheds from other occupied sites within western Newfoundland. Recolonization of insular Newfoundland following extirpation of the species might occur, but would depend on very infrequent dispersal events. The shortest possible route for rescue would be across the Strait of Belle Isle from Labrador; however, this route is unavailable because Banded Killifish does not occur in Labrador.

THREATS AND LIMITING FACTORS

Limiting Factors

As indicated by Chippett (2004), there appears to be an abundance of suitable habitat available in insular Newfoundland, i.e. shallow freshwater habitat with slow current, soft bottom, and abundant vegetation. The principal limitation appears to be accessibility and connectivity (Fisheries and Oceans Canada 2011). Extensive estuaries are not a general feature of the Newfoundland coastline, so dispersal among freshwater drainages via the marine route is difficult. Furthermore, much of the habitat that could potentially be used by Banded Killifish in Newfoundland lies above falls and/or rapids that are barriers to upstream dispersal. Notwithstanding the presence of impassible barriers, Banded Killifish does not appear to move extensively. The Indian Bay watershed population is confined to a relatively small area even though physical barriers to dispersal do not prevent movement to other areas (although patches of suitable habitat are separated by areas of deeper water, rocky substrate, and little vegetation). Despite the abundance of habitat, the populations are largely fragmented (less so for those along the southwest coast), and presumably there is little or no gene flow among them.

Threats

The most significant threat to Newfoundland populations of Banded Killifish is habitat sedimentation resulting from forest harvesting activity and road development (Chippett 2003; Fisheries and Oceans Canada 2011). Altered water flow patterns and impediments to migration, also resulting from road development, have been identified as additional threats. The level of concern assigned to elevated sediment loading and alteration in water flow regimes were rated as medium-high to high (Fisheries and Oceans Canada 2011). Sediment loading is considered to be deleterious to Banded Killifish for several reasons. Invertebrate populations can be negatively affected and aquatic vegetation can be smothered by increased suspended sediment (Waters 1995). Fish can be harmed directly as well through damage to gill tissues and increased susceptibility to disease and predation (Fisheries and Oceans Canada 2011). It is relevant to note that no-cutting buffers of 500 – 1,000 m in width have been established in the Indian Bay watershed, the area considered to be at highest risk of anthropogenic sediment loading in the near term. Furthermore, watercourses usually affected by sedimentation caused by forestry activities are first- and second-order streams. As Banded Killifish does not usually occur in these streams, it may not be threatened by such activities (Fisheries and Oceans Canada 2011).

Other threats, including pollution (originating from road development, mineral exploration, and urban/cabin development), bait harvesting, and fishery by-catch are assigned low to medium levels of concern. In addition, the rapid development of cabins in riparian areas threatens Banded Killifish through shoreline development and pollution (Shelley Pardy, pers. comm.). Banded Killifish is also potentially threatened by the American Eel fishery, particularly on the west coast of Newfoundland. It is caught as by-catch along with several other species in fyke nets and baited pots. In 2006, by-catch in the eel fishery in the St. George's Bay area was monitored by personnel from the Mi'kmaq Alsumk Mowimsikik Koqoey Association (MAKMA) and Fisheries and Oceans Canada. Efforts were also made to inform eel fishers about methods to minimize mortality in by-caught animals, particularly Banded Killifish. Mortality of by-caught Banded Killifish appears to be below one percent (MAKMA 2006).

Introduced predatory species, particularly Brown Trout and Rainbow Trout, likely represent an additional threat. Both of these species were introduced to the Avalon Peninsula in the late 1800s and are now established in many watersheds. Brown Trout is most common on the Avalon Peninsula although it is believed to be expanding westward; it is present in both First Pond and Backup Pond in the Indian Bay watershed. Rainbow Trout have spread widely across Newfoundland (van Zyll de Jong *et al.* 2004). Brown Trout and Rainbow Trout are anadromous and make extensive use of estuarine and marine habitats. The degree to which these species threaten Banded Killifish is not known.

The IUCN Threats Calculator for Banded Killifish in Newfoundland is shown in Appendix 1. The overall threat impact is high.

Number of Locations

The most important threat to Banded Killifish is sediment loading that emanates from numerous point sources scattered across the species' range. Because the point sources are largely independent, no single catastrophic event has the potential to cause extirpation of Banded Killifish in Newfoundland. The sites where the species occurs are therefore considered to be separate locations with two exceptions. The first is several sites clustered around St. George's Bay that are treated as one location. The newly discovered population in Pinchgut Pond is considered part of that location because its watershed (Harry's Brook) drains into St. George's Bay. The second exception is two sites on the Burin Peninsula, Freshwater Pond and Winterland (the latter identified by Chippett (2003) only as a "pond in the town of Winterland"), which lie in close proximity to each other (less than 5 km) and drain into Placentia Bay to the east. These two sites are considered to be one location. The other site on the Burin Peninsula, Garnish Pond, lies approximately 10 km to the north and drains into Fortune bay to the west. This site is considered to be a separate location.

There are ten locations in total (Figure 1). Burton's Pond in St John's is not included as the population is introduced. Similarly, the unconfirmed populations in Main Brook and Western Brook are not included. Additional locations may be discovered with further survey work, especially along the west coast.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

The Banded Killifish (Newfoundland populations) is currently listed as Special Concern under Schedule 1 of the Canadian *Species at Risk Act* (SARA). It has been assessed as Not at Risk in other parts of its Canadian distribution. The species is also listed as vulnerable under the Newfoundland and Labrador *Endangered Species Act*.

Non-Legal Status and Ranks

Banded Killifish has a General Status Ranking of *Sensitive* in Newfoundland (Newfoundland and Labrador Department of Environment and Conservation 2013).

Banded Killifish has a global ranking of G5 (latest review January 2012) and national status of N5 in both Canada and the United States (December 1996). Provincial ranks in Canada are S5 (New Brunswick, Nova Scotia, Ontario, and P.E.I.), S4 (Quebec), and S1 (Manitoba and Newfoundland) (NatureServe 2013). State rankings in the United States are S5 (District of Columbia, Maine, Maryland, Massachusetts, Michigan (S4S5), New Jersey, New York, and Pennsylvania), S4 (Connecticut, Delaware, Indiana, New Hampshire, North Carolina, Ohio, Vermont, Verginia, and Wisconsin (S3S4)), S3 (North Dakota and Rhode Island), S2 (Iowa and West Virginia) and S1 (Illinois and South Dakota).

Habitat Protection and Ownership

The federal *Fisheries Act* protects fish habitat in Canada for species subject to active fisheries. Banded Killifish therefore would be expected to benefit from habitat protection provided to drainages containing game fishes or commercially harvested species. This does not apply to all populations. The Newfoundland and Labrador *Endangered Species Act* also lists Banded Killifish as a vulnerable species. As Banded Killifish is not known to occur in either of Newfoundland and Labrador's national parks (report from Gros Morne National Park (Western Brook) remains unconfirmed), the species is not afforded protection under the *Canada National Parks Act*.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Personnel from the following agencies provided information for this report: Fisheries and Oceans Canada, Government of Newfoundland and Labrador Department of Environment and Conservation, Government of Newfoundland and Labrador Department of Natural Resources, Memorial University of Newfoundland, Mi'kmaq Alsumk Mowimsikik Koqoey Association, Parks Canada, and Environment Canada. Thanks to Jenny Wu from the COSEWIC Secretariat for help with mapping.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Dr. Tim Birt is a Research Associate and Adjunct Assistant Professor at Queen's University. Most of his research activities involve studies of population genetics and evolution of seabirds and Atlantic Salmon. Tim has authored or co-authored three COSEWIC reports.

COLLECTIONS EXAMINED

None

Appendix 1. IUCN Threats Calculator result for Banded Killifish in Newfoundland.

THREATS ASSESSMENT WORKSHEET		
Species or Ecosystem Scientific Name	Banded Killifish, Newfoundland Populations	
Element ID		**Elcode**
Date (Ctrl + ";" for today's date):	18/08/2013	
Assessor(s):	Tim Birt with input from John Post, FWF SSC and during SAM assessment	
References:		

Overall Threat Impact Calculation Help:

		Level 1 Threat Impact Counts	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	0	0
C	Medium	1	1
D	Low	3	3
	Calculated Overall Threat Impact:	High	High
	Assigned Overall Threat Impact:		
	Impact Adjustment Reasons:		
	Overall Threat Comments		

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
1.3	Tourism & recreation areas	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	cabin development
2	Agriculture & aquaculture						
3	Energy production & mining						
4	Transportation & service corridors	C	Medium	Restricted (11-30%)	Serious (31-70%)	High (Continuing)	
4.1	Roads & railroads	C	Medium	Restricted (11-30%)	Serious (31-70%)	High (Continuing)	silt loading, altered water flow regime, impediment to migration
4.2	Utility & service lines		Not Calculated (outside assessment timeframe)	Restricted (11-30%)	Moderate (11-30%)	Low (Possibly in the long term, >10 yrs)	hydro line development
5	Biological resource use	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting	D	Low	Pervasive (71-100%)	Slight (1-10%)	Moderate (Possibly in the short term, < 10 yrs)	silt loading - Forest harvesting is most likely to occur in Indian Bay Watershed where substantial buffers (500-1000m) have been established along watercourses.
5.4	Fishing & harvesting aquatic resources	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	by-catch, bait harvest - Mortality of Banded Killifish captured in eel fishery is estimated to be <1 percent. Impact of use of Banded Killifish as bait is unknown.
6	Human intrusions & disturbance						
7	Natural system modifications						
8	Invasive & other problematic species & genes		Unknown	Unknown	Unknown	Unknown	
8.1	Invasive non-native/alien species		Unknown	Unknown	Unknown	Unknown	invasive Brown Trout, Rainbow Trout
9	Pollution	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
9.1	Household sewage & urban waste water	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	sewage from cabins
9.2	Industrial & military effluents	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	mineral exploration
9.3	Agricultural & forestry effluents	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	road construction
10	Geological events						
11	Climate change & severe weather						